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TITLE

**STUDIES OF THE RESISTANCE OF PINE HYBRIDS
TO BARK-BEETLE ATTACKS**

SEASON OF 1951

**A REPORT OF STUDIES CONDUCTED AT THE
INSTITUTE OF FOREST GENETICS
IN COOPERATION WITH THE CALIFORNIA
FOREST AND RANGE EXPERIMENT STATION**

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SUBJECT-

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STUDIES OF THE RESISTANCE OF PINE HYBRIDS TO BARK-BEETLE ATTACKS

INTRODUCTION

During the past 25 or more years, geneticists of the Institute of Forest Genetics have been making great progress in the development of pine hybrids. They have developed hybrids with many different desirable characters; however, the question of whether or not these trees would be resistant to the various insect enemies of our pine forests could not be answered until the new pine hybrids were of sufficient size to be tested for insect susceptibility or resistance.

In response to these inquiries into the relative susceptibility or resistance of various hybrid pines to insect attacks, John M. Miller of this office was assigned in 1946 to the Institute of Forest Genetics, Placerville, California, to conduct various tests on the available hybrids. Although these were the first tests of their kind to be conducted on hybrid pines, the studies definitely pointed out the fact that the insect resistance of a given species of pine was an inheritable factor, as was expected, and that such resistance could be transmitted to its hybrid progeny just as factors of growth habit or form, rapidity of growth, and resistance to drought, frost, and disease are transmitted to hybrid offspring.

Miller's initial studies concerned the resistance of young pine trees to the pine reproduction weevil, Cylindrocopturus eatoni Buch. For many years this insect had been a serious pest of young trees, particularly those in the brushfield plantations of northern California. Miller (1950) studied the resistance of various species and hybrids to this weevil and found (1) that individual trees of any given species vary widely in their resistance, (2) that all trees of certain species, Coulter pine, Pinus coulteri Lamb., for example, were resistant, and (3) that "resistance of the Jeffrey-Coulter cross was greatly improved over that of its Jeffrey parent (Pinus jeffreyi "Ore. Comm.") by introduction of the resistant Coulter pine strain."

Following the success of Miller's early work, several conferences were held in which a cooperative plan was developed for the continuation and expansion of these studies. This plan proposed the incorporation of studies of bark-beetle resistance in addition to the continuation of the weevil resistance studies. Such studies were to be conducted by the Bureau of Entomology and Plant Quarantine in cooperation with the Institute of Forest Genetics, California Forest and Range Experiment Station, on trees currently being produced at the Institute. The project has been approved on the basis of a ten-year program by both agencies. The writers were assigned to these studies for the season of 1951. This report presents the results of the first season of work.

STUDIES UNDERTAKEN DURING 1951 SEASON

Preliminary tests of bark-beetle resistance by Miller (1950) had shown that the western pine beetle, Dendroctonus brevicornis Lec., was very specific in its host selection and that a natural Jeffrey-ponderosa pine hybrid apparently was resistant to this insect. It was proposed that these tests be repeated and extended in 1951 to include other Dendroctonus species which attack Jeffrey and ponderosa pine, Pinus ponderosa Laws. A large number of trees were made available by the Institute for this study. These included the following pines: Jeffrey, ponderosa, F 1 Jeffrey-ponderosa hybrids, and natural Jeffrey-ponderosa hybrids.

Procedure

In preparation for the cage tests conducted during the summer of 1951, all the trees selected for the tests were pruned to a height of ten to twelve feet to permit the installation of the cages. This pruning caused a great deal of pitch flow on the trunk of the tree; however, this could not be avoided because of the late date of pruning. Perhaps it might have been more desirable to postpone the tests until the test trees had recuperated a year or more. However, such a delay was not considered essential, and the tests were conducted immediately after the pruning had been completed.

An oleoresin sample was taken from each tree by means of a sealed tapping device developed on the pattern of the Gillmer apparatus by N. T. Mirov and E. F. Kimbrough of the Institute staff (see Plate XI). These samples were collected and refrigerated at 42° F. until they could be analyzed at the conclusion of the summer field season. Laboratory facilities for the distillation and analysis of the turpentine were provided by the School of Forestry, University of California. The oleoresin samples were collected so that an analysis could be made of the turpentines to determine the derivation of the trees used in each test, particularly of those trees in the Pyramid Guard Station area where there was a chance of accidentally using a hybrid.

After the oleoresin samples had been secured, the test trees were caged by the authors with the help of the staff of the Institute of Forest Genetics. The cages which were used in these tests were of a new type developed by Callahan and Miller (1952) for use this season. The cylindrical, sleeve-type, cages were all constructed on the same general principle although some were constructed with 28-mesh, plastic screen and others of 16-mesh, bronze screen. The installed cages are shown in Plate XII.

The beetles used in these tests were secured from various points in the northern half of the State where they were available at the time at which they were needed. The western pine beetle brood material was obtained locally in the vicinity of Placerville, California, and from an area

near the Blacks Mountain Experimental Forest, Lassen County. The brood material of the mountain pine beetle, Dendroctonus monticolae Hopk. was procured from a large infestation on the shores of Crystal Bay at the north end of Lake Tahoe, Nevada. The brood material of the Jeffrey pine beetle, Dendroctonus jeffreyi Hopk., was procured from an infested tree near Hat Creek, Lassen County, California.

In general, two techniques were used in the introduction of the beetles into the cages. In all of the mountain pine beetle and some of the western pine beetle tests the brood material was placed inside of the cage (see Plate XII); the beetles emerged naturally and made their attacks on the trees. In all of the Jeffrey pine beetle and some of the later western pine beetle tests the insects were reared from the brood material in a rearing room; then, only the adult beetles of the desired species were released in the cages. Obviously, only in the case of the latter procedure was it possible to determine the number of beetles used in the tests and to exclude the large numbers of predaceous clerids which contaminated the cages when the first technique was used.

It was anticipated that there might be some mortality resulting from the various forced attacks which were made; hence, most of the tests were replicated. It soon became apparent, however, that none of the caged trees would die from the restricted nature of the forced attack. Therefore, the comparative success or failure of each attack was based on an examination of the pitch tube development and gallery pattern on each tree. Successful attacks were those in which the pitch flow was copious or galleries were extended. Unsuccessful attacks were those in which there was little or no pitch flow and no gallery extension.

It was obvious from the examinations that all of the attacks on any one tree followed the same general pattern and that the attacks on other replications in the same test were similar without exception. Therefore, the data presented in the appended plates has been aggregated to give the general condition which prevailed in each test. In the future, only two replications of each test need be made to secure the best utilization of all cages in the maximum number of tests.

In all of the tests it was necessary to provide some ant control measures. Aldrin, when poured on the soil which covered the bottom of the screen cages, proved to be an effective means of ant control. In one cage (western pine beetle vs. ponderosa pine) a lizard was found to be consuming the beetles at the conclusion of the test as rapidly as they were liberated in the cage, and this proved to be an insurmountable difficulty. However, it presented itself just as the test was being concluded and, thus, had only a limited effect on the test.

Observations of the progress of the attack were made at irregular intervals throughout the summer, and at the close of the season the cages were dismantled. The approximate number of attacks was determined on each tree, and several galleries on each tree were excavated to determine the nature and success of the attacks. Photographs were taken

of the general distribution of attacks, the size and shape of the pitch tubes, and the gallery pattern. These photographs have been used in the preparation of Plates I - X.

Tests Conducted

Miller's first tests of bark-beetle resistance in 1950 indicated that a natural Jeffrey-ponderosa hybrid was resistant to the western pine beetle. In that a large number of F₁ Jeffrey-ponderosa hybrids of a suitable age were available at the Institute of Forest Genetics, it was decided to conduct a series of replicated tests ^{1/} of the resistance of these trees to the various bark beetles of the genus Dendroctonus which normally attack the parent trees.

In addition to the tests on the hybrids, several tests were made of the host specificity and oleoresin tolerance of each of these three species of bark beetles. Some of these tests were conducted at the Institute of Forest Genetics on trees of the same age and size as the hybrids. However, because of the lack of sufficient numbers of trees at the Institute, it was necessary to conduct many of the tests in the vicinity of the Pyramid Guard Station on the Eldorado National Forest. This area was one in which lower-elevation, ponderosa pine mixed with the higher-elevation, Jeffrey pine. Since trees of both species occurred within a few feet of each other, any influences of altitude and site were eliminated from these particular tests.

The results of the hybrid tests indicate that the F₁ Jeffrey-ponderosa hybrid is not resistant to the Jeffrey pine beetle or the mountain pine beetle, although it apparently is resistant to the western pine beetle as is the natural Jeffrey-ponderosa hybrid. A complete description of the nature of the attack by these three beetles and the resistance of the hybrids is given in Plates I - III.

The other tests conclusively showed (1) that the western pine beetle would start to attack Jeffrey pine (Plate V), (2) that the Jeffrey pine beetle would start to attack ponderosa pine (Plate VII), and (3) that the mountain pine beetle would start to attack Jeffrey pine (Plate IX), but that in each case the oleoresins of these pines apparently were toxic to the respective beetles. In the case of the western pine beetle the beetles bored directly through the bark to the phloem, but, as far as it could be ascertained, the first oleoresin flow from the exposed phloem surface killed the beetles (Plate V). In the case of the mountain pine beetle and Jeffrey pine beetle similar conditions prevailed. However,

^{1/} The replications were in triplicate in all cases, except those where a statement is made to the contrary on the respective plates.

the only apparent difference was that these larger beetles seemed to be able to tolerate the oleoresin for a slightly longer period of time. Perhaps the apparent delay in the toxic effect was influenced in some manner by the relative size of the beetles. Both of these beetles, being larger than western pine beetle, may have lived longer as a result of some internal processes which would fluctuate with the body size. For example, the relative amounts of stored food stuffs in the insect's body may vary with the body size, and, thus, energy potential may vary directly with beetle size. In all cases these three beetle species were able to carry out a prolonged attack on their normal host species (Plates IV, VIII, X). The comparative sizes of the pitch tubes made by the Jeffrey and mountain pine beetles on different hosts is shown in Plates XIII and XIV.

These latter tests also conclusively showed that there was an absolute, physiological distinction between the mountain pine beetle and the Jeffrey pine beetle on the basis of their ability to tolerate the oleoresins of different pine species. For example, the mountain pine beetle readily attacked ponderosa pine and sugar pine, *Pinus lambertiana* Dougl., (Plates VIII and X) but not Jeffrey pine (Plate IX), whereas, the Jeffrey pine beetle readily attacked Jeffrey pine (Plate VI) but not ponderosa pine (Plate VII). Although these beetles showed this definite physiological differentiation, it is well known that they are scarcely distinguishable morphologically.

A knowledge of the oleoresin composition of each test tree was considered to be necessary because the composition may have some effect on the host specificity of the bark beetles used in these tests (Callahan, 1952). Many workers previously have shown that the pines are specific in their oleoresin composition, and Mirov (1932) and Zobel (1951) have shown that natural hybrids can be detected from the parental species by means of an analysis of the turpentine obtained from steam distillation of the oleoresins. Hence, the oleoresin sample obtained from each tree was treated by steam distillation to separate the volatile from the non-volatile fraction. An analysis then was made of the physical and chemical properties of the volatile fraction, turpentine. An oleoresin sample was not secured from every tree because some of the trees would not bleed; however, the physical properties of the turpentine of most of the test trees are presented in Table 1 and figure 1.

It is particularly interesting to note that tree numbers Py 10, 3, 5, 2, and IFG 11 were all subjected to mountain pine beetle attacks, and, although IFG 11 did not seem to be resistant to these beetles, the other trees did seem to be resistant. This is rather significant because all of the trees in this group seem to form a series of hybrids or hybrid derivatives intermediate in their oleoresin characters between Jeffrey pine and the F₁ Jeffrey-ponderosa hybrid. Perhaps there is a critical point in such a series when the composition of the oleoresin becomes such that the beetles no longer can tolerate it.

Conclusions

The following conclusions have been drawn from these limited tests of (a) the resistance of hybrid pines to bark beetles and (b) the host

specificity of various species of Dendroctonus.

- (1) Under the conditions of these tests, both the natural and F₁ Jeffrey-ponderosa hybrids (22 years of age) are resistant to the western pine beetle.
- (2) Under the conditions of these tests, the F₁ Jeffrey-ponderosa hybrids (22 years of age) show little or no resistance to the Jeffrey pine beetle and the mountain pine beetle.
- (3) The western pine beetle will attack Jeffrey pines, but the oleoresin appears to be toxic to the beetles.
- (4) The Jeffrey pine beetle will attack ponderosa pines, but the oleoresin appears to be toxic to the beetles.
- (5) The mountain pine beetle from ponderosa and sugar pine brood material will attack Jeffrey pines, but the oleoresin appears to be toxic to the beetles.
- (6) The mountain pine beetle from ponderosa pine brood material will successfully attack young sugar pines.
- (7) The mountain pine beetle from sugar pine brood material will successfully attack young ponderosa pines.

The results of the host specificity tests further substantiate the hypothesis that one of the factors which account for the host specificity of a given insect species is its ability to tolerate the oleoresin of certain pine species. The oleoresin is the only defense mechanism of the tree, and it is the first factor with which the insects must contend. These tests also indicate that when an insect can tolerate the oleoresin of a given pine, then the quantity of resin produced by individual trees becomes a critical factor in the success or failure of an attack.

SUGGESTIONS FOR FURTHER WORK

The studies of the resistance of pine hybrids, which have been completed to date, indicate that some hybrids are resistant to certain bark beetles, but that others are not. Similar tests should be conducted in the future on any hybrids which are available. It should be stressed, however, that these are purely empirical tests which contribute very little to our basic understanding of the factors which condition susceptibility or resistance of pines to bark beetles.

On the other hand, the results of this season's studies of bark-beetle host specificity have further confirmed the opinion that the composition of the host oleoresins is the determining factor in host specificity. Further studies in this field should be conducted in an attempt to accurately determine whether bark beetles of various species can tolerate only certain oleoresins, whereas other oleoresins are toxic to them. Ultimately, such studies may show that individual components or groups of components in the oleoresin of a given pine species cause it to be toxic

to certain species of insects.

One way to determine the relative toxicity of the oleoresins of different pine species to a given insect species is to run a series of caged attacks on pines having distinctly different oleoresin components. For example, the resistance of the western pine beetle to *N*-heptane can be tested by forcing attacks on Digger and Jeffrey pines which have 95 percent *N*-heptane in their turpentine. Its resistance to smaller amounts of *N*-heptane can be tested by forcing attacks on Coulter pine which has 15 percent *N*-heptane in its turpentine. Its resistance to 1-limonene can be tested by forcing attacks on Torrey pine which has 75 percent 1-limonene in its oleoresin. Similarly, many other tests can be made by forcing attacks on pines which have different oleoresin constituents.

Perhaps a more direct approach to the problem would be to use known concentrations of the various oleoresins or their components and actually to apply these substances to the insects. An apparatus has been developed for applying known quantities of insecticides to insects, and it seems logical to assume that such an apparatus could be used in these tests.

Dr. A. B. Anderson, of the University of California, has suggested that another way of testing the responses of the beetles to individual oleoresin components would be to spray the components directly onto the bark of trees of a species which the insect normally attacks and then force the beetles on the sprayed trees.

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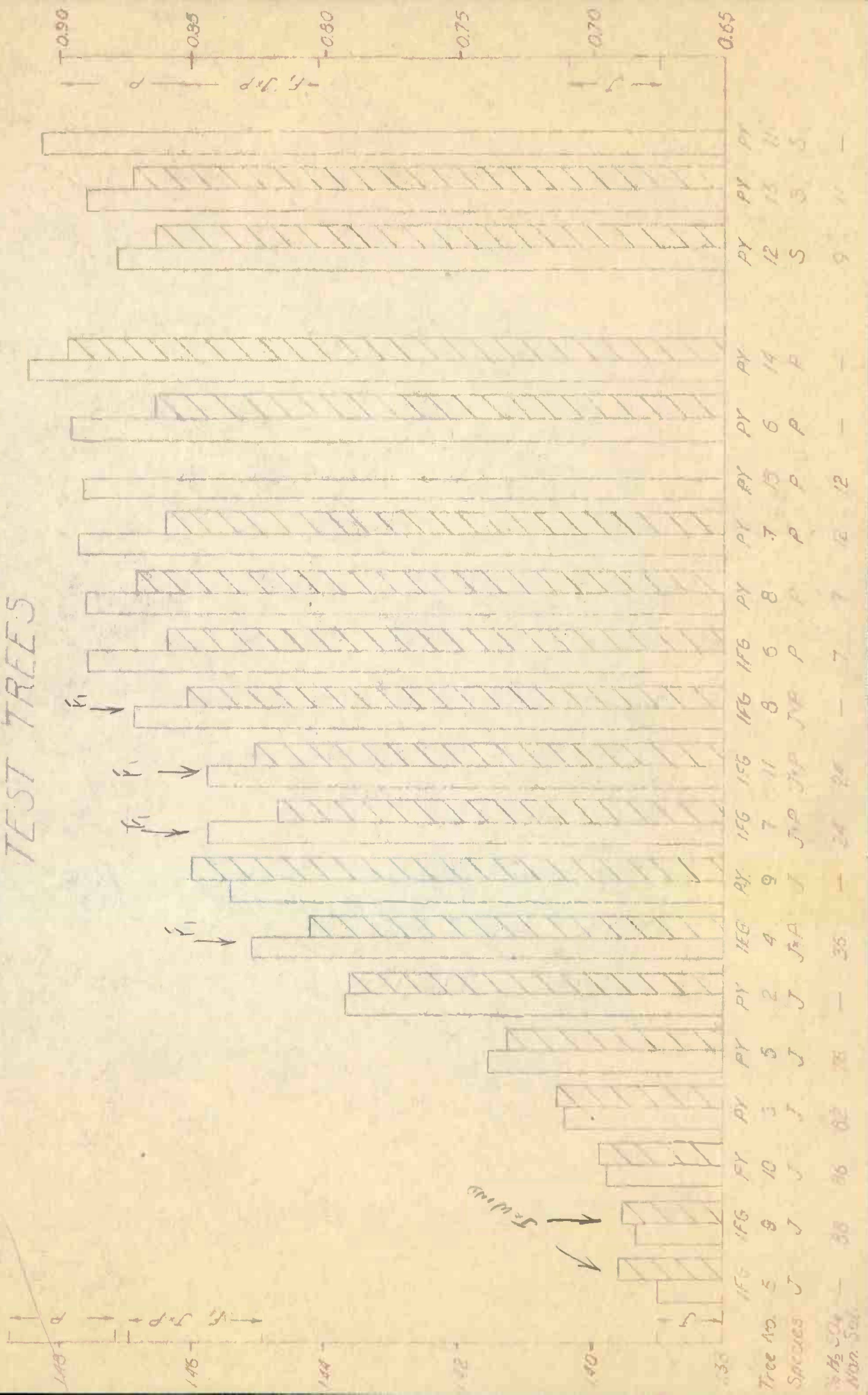
TABLE NO. 1 - PROPERTIES OF TURPENTINE FROM TEST TREES

Tree No.	Tree 1/ Species	Physical Properties 2/		Spec. Gravity	Sulphuric Non-Soluble
		Optical Rotation	Index Refraction		
176	1	---	---	---	---
	2	---	---	---	---
	3	---	---	---	---
	4	F ₁ J x P	-7°00'	1.4506	36%
	5	J	---	1.3898	---
	6	P	-17°00'	1.4756	7%
	7	F ₁ J x P	-12°40'	1.4574	24%
	8	F ₁ J x P	---	1.4678	---
	9	J	0°00'	1.3929	85%
	10	---	---	---	---
	11	F ₁ J x P	4°00'	1.4574	24%
PT	---	---	---	---	---
	2	J	---	1.4369	---
	3	J	0°00'	1.4039	82%
	---	---	---	---	---
	5	J	0°00'	1.4153	76%
	6	P	-15°20'	1.4783	---
	7	P	-23°40'	1.4768	12%
	8	P	-3°40'	1.4758	7%
	9	J	---	1.4541	---
	10	J	0°00'	1.3971	86%
	11	S	---	1.4829	---
	12	S	+24°00'	1.4716	9%
	13	S	+8°00'	1.4761	11%
	14	P	---	1.4844	---
	15	P	---	1.4766	12%
	---	---	---	---	---

- 1/ J = Jeffrey pine
P = Ponderosa pine
J x P - Jeffrey x ponderosa pine
S = Sugar pine
- 2/ All properties measured at 23.5° C.
- 3/ Natural hybrid

Fig. 1

PROPERTIES of TURPENTINE from 1951 TEST TREES



PLATES

All photographs in the following section were taken by Dr. J. W. Duffield, Research Forester, Institute of Forest Genetics, who graciously gave his time and interest to the entire project.

Plate I

Western Pine Beetle vs. Jeffrey-ponderosa Pine



A



B

- A. Closeup of region of attacks - Few, scattered, small pitch-tubes. No external evidence of the many attacks hidden beneath the bark flakes.
- B. Closeup of excavated galleries - Thumb tacks mark entrance to galleries. Broken ink lines denote direction and extent of bark galleries. Solid ink lines denote extent of heavy pitch deposits in short phloem galleries.

Description of Test

No. of Cages: 3 (170 1. 3. 4)

Age of trees: 22 years

Beetles

Host: Ponderosa Pine

Location: Central, westside Sierra - near Placerville, California

Rearing: Natural emergence from infested brood bark placed inside of cage.

Attacks

Bark Surface Area: 26.5 sq. ft./tree

Number of Attacks: 150. Probably this figure is much too low. When an attempt was made to count the attacks on these trees, it soon became apparent that there were only a few visible attacks per square foot of bark surface. However, after several of the large bark flakes had been removed, it was apparent that a small amount of pitchy frass indicating still more unsuccessful attacks was to be found under nearly every bark flake.

Distribution of attacks: The attacks were evenly distributed over the bark surface.

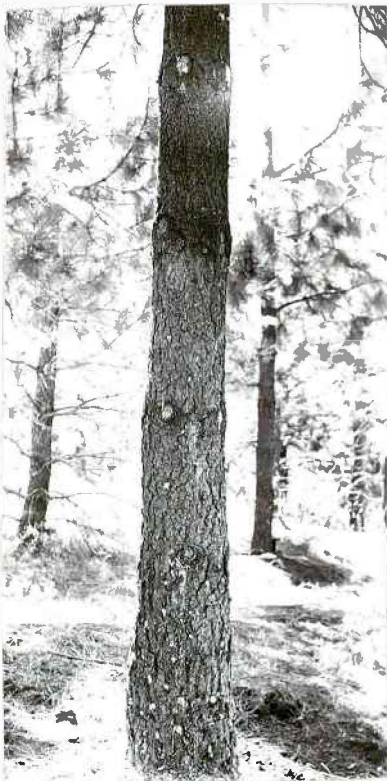
Pitch tubes: Definite, small pitch tubes were formed, but they were not nearly as large as the pitch tubes made by this beetle on ponderosa pine (Plate IV).

Galleries: In most cases the attacks just penetrated the outer phloem, where two dead adults, presumably a male and a female, were to be found cemented together. In no cases did the gallery reach the sapwood, and only in a very few cases did it extend as much as 1/2" laterally through the phloem.

Significance: Apparently this beetle could tolerate the oleoresin of these hybrids only for a very short time, if at all. This hybrid, at this age, appears to be resistant to this beetle.

Plate II

Jeffrey Pine Beetle vs. Jeffrey-ponderosa Pine



A



B

- A. Distribution of attacks - Heaviest concentration at base of tree.**
- B. Closeup of region of attacks - large pitch tubes adjacent to excavated galleries. Thumb tacks mark entrances to galleries, and ink lines show direction and length of gallery extension.**

Description of Test

No. of Cages: 2 (175 7.5)

Age of Trees: 22 years

Beetles

Host: Jeffrey pine

Location: Northern, eastside Sierra - near Hat Creek, California

Rearing: Beetles were removed from the brood tree after the bark was peeled off, and later the beetles were placed in the cages.

Attacks

Bark surface area: 24.5 sq. ft.

Number of attacks: 125.

Distribution of attacks: Most of the attacks were made on the basal three feet of the trunk.

Pitch tubes: Rather large pitch tubes; the size seemed to be proportional to the length of the gallery. Dead beetles occasionally were found in pitch tubes.

Galleries: Beetles bored somewhat obliquely through the bark to the phloem. Galleries just touched the sapwood, which was slightly resined beneath the gallery. The phloem tissue adjacent to the gallery was brown and apparently dead about 1/8-1/4" back from the gallery. The walls of the galleries were pitchy, and the pitchy frass was packed loosely in the galleries. Occasionally dead adults were found in the galleries.

Significance: Apparently these beetles could tolerate the oleoresin of this hybrid.

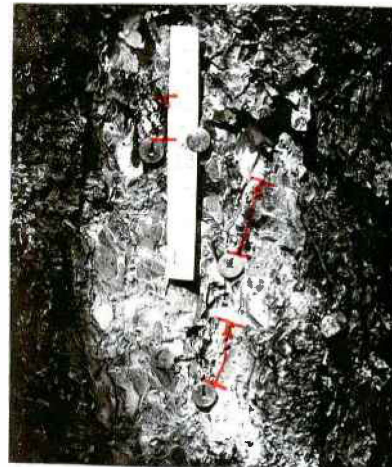
*Very
intensely*

Plate III

Mountain Pine Beetle vs. Jeffrey-ponderosa Pine



A



B

- A. Scattered distribution of attacks - Arrows point to pitch tubes.
- B. Closeup of region of attacks - Thumb tacks mark entrances to galleries, and ink lines show direction and length of gallery extension.

Description of Test

No. of Cages: 2 (IFG 11, 12)

Age of trees: 22 years

Beetles

Host: Ponderosa pine (IFG 11), sugar pine (IFG 12).

Location: Central Sierra, 6000 ft. Crystal Bay, North shore of Lake Tahoe, Nevada.

Rearing: Natural emergence from infested brood logs placed inside of cage.

Attacks

Bark surface area: 25.0 sq. ft. (IFG 11); 22.0 sq. ft. (IFG 12).

Number of attacks: 53. (IFG 11). 162. (IFG 12). Many attacks under bark flakes were not included in these counts.

Distribution of attacks: Attacks were scattered at random over bark surfaces.

Pitch tubes: Pitch tubes were smaller than those of the Jeffrey pine beetle. Pitch tubes size was proportional to the length of gallery.

Galleries: Beetles bored more or less directly into the phloem and then turned upward. Galleries usually touched the sapwood, where they caused some resin impregnation of the wood, and they turned upward in an irregular winding course. The phloem for 1/4-1/2" surrounding the gallery was resin impregnated. The galleries in IFG 11 were 2-3" in length, and in IFG 12 they did not exceed 2" in length.

Significance: Apparently these beetles can tolerate the oleoresin of this hybrid. The difference in gallery length in the two trees tested may be correlated with the resin production. IFG 12 seemed to be less resistant than IFG 11 on the basis of pitch-tube size and gallery length. This may have been correlated with the fact that it did not produce any resin when tapped, while IFG 12 produced a considerable amount.

Plate IV

Western Pine Beetle vs. Ponderosa Pine



A



B

- A. Closeup of region of attack - Large, yellow pitch tubes.
1/3 natural size.
- B. Closeup of excavated galleries. Ink lines outline pitchy
areas in phloem beneath beetle entrance holes. 2x.

Description of Test

No. of Cages: 1 (IFO 6)

Age of Tree: 22 years.

Beetles

Host: Ponderosa pine.

Location: Central, westside Sierra - Near Placerville, Calif., and northern, eastside Sierra - Near Hat Creek, Calif.

Rearing: Natural emergence from infested brood bark placed inside of cage in the case of the Placerville material; in the case of the Hat Creek material, the brood bark was placed in a rearing room and as the beetles emerged they were collected and placed in the cage. At the end of the test a lizard was found to be consuming the insects as fast as they were placed in the cage.

Attacks

Bark surface area: 27.0 sq. ft. / tree

Number of attacks: 120 attacks represented by pitch tubes were found. However, over 3500 adults were liberated in this cage during the final two weeks of the field season. Either the lizard did away with a very large number of these, or else something else deterred them from making attacks.

Distribution of attacks: Most of the attacks were on the basal 3 feet of the stem, but they went to the top of the cage on the north side of the stem.

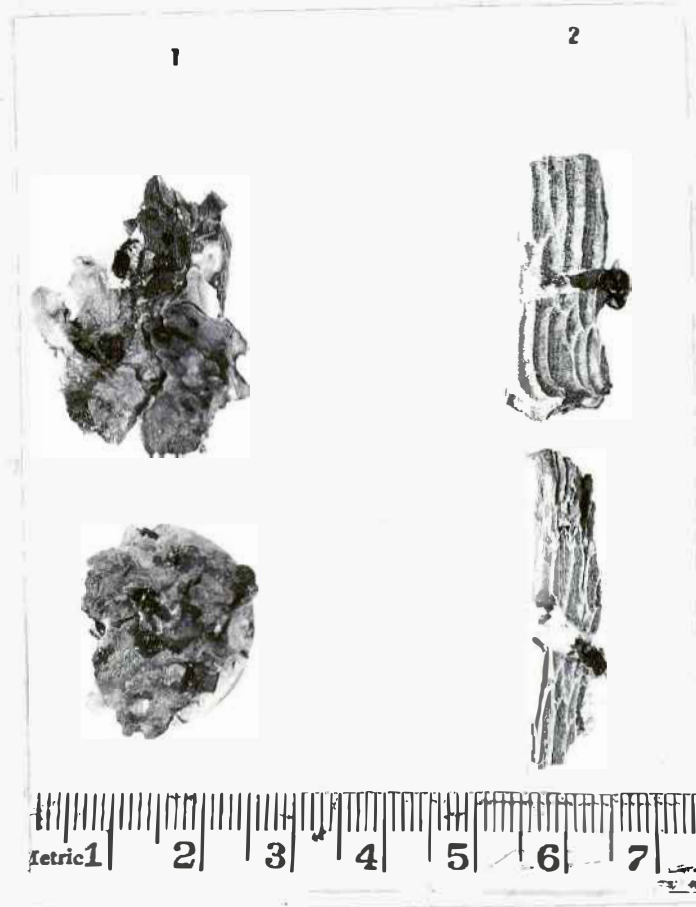
Pitch tubes: Pitch tubes were large for this insect, and resembled those found on trees which have resisted attacks of this beetle.

Galleries: The galleries were very short, 1/2". Phloem surrounding galleries was very heavily stained (brown).

Significance: The oleoresin of this tree was not toxic to this insect, but the pattern of attack indicated that the flow was too copious for the insects. Apparently the beetles just exhausted themselves.

Plate V

Western Pine Beetle vs. Jeffrey Pine



1. Surface view of western pine beetle adults trapped in the pitch flow from the gallery opening into the phloem. Note that the pitch flow only covers a very small portion of the beetle.
2. Cross section of western pine beetle galleries showing how galleries penetrate just to the phloem (at left).

Description of Test

No. of cages: 3 (IFG 2, 5; Py 1)

Age of trees: 22 years (IFG).

Beetles

Host: Ponderosa pine.

Location: Central, westside Sierra - near Placerville, Calif.

Rearing: Natural emergence from brood bark placed inside cages.

Attacks

Bk surface area: 28.0 sq. ft./tree

Number of attacks: Apparently there were a large number of attacks on these trees, but because of the nature of the attacks, exact counts could not be made.

Distribution of attacks: Not known.

Pitch tubes: None.

Galleries: The beetles bored directly through the bark until they cut through the last bark plate into the phloem. Apparently the first resin flow from the phloem was absolutely toxic to the beetles, and they were killed very soon. In all cases the attacks were made by single beetles, presumably females.

Significance: The oleoresin of this pine appeared to be definitely toxic to this beetle. The pattern of attack indicated that the male did not join the female in the construction of the gallery until the female encountered the pitch flow from the phloem and began to remove it from the gallery.

Plate VI

Jeffrey Pine Beetle vs. Jeffrey Pine



A



B



C

- A. Distribution of attacks - Heaviest concentration at base of tree.
- B. Closeup of pitch tubes - Very large, sticky pitch masses.
- C. Closeup of excavated galleries - Thumb tacks mark entrances to galleries, and ink lines show direction and length of gallery extension.

Description of Test

No. of Cages: 1 (I79 9).

Age of Tree: 22 years.

Beetles

Host: Jeffrey pine.

Location: Northern, eastside Sierra - near Hat Creek, California.

Rearing: Beetles were removed from the brood tree after the bark had been peeled off, and later the beetles were placed in the cage.

Attacks

Bark surface area: 32.0 sq. ft.

Number of attacks: 100. The count of the number of attacks was probably far below the actual number. In some cases the pitch tubes were broken off, and the only evidence of an attack was the beetle entrance hole which was hard to distinguish.

Distribution of attacks: The attacks were concentrated on the lower 3-4 feet of the bole. These beetles showed a negative phototropism when released in the cage, and this may have accounted for their attacking the lower bole rather than climbing around and making a more random attack.

Pitch tubes: The pitch tubes on this tree were the largest of all. However, the size of the pitch tube on this tree was not proportional to the length of the gallery. Long galleries had smaller pitch tubes, and short galleries had larger pitch tubes, which may indicate that as the pitch flow diminishes the beetles may have more time for gallery construction.

Galleries: The beetles bored directly into the phloem, and then they turned and worked upward for a very short distance, never exceeding 2". In most of the galleries which were excavated, there were one or two adults at the uppermost end of the galleries. Apparently these adults had died of exhaustion.

Significance: This beetle tolerated the oleoresin of this tree as evidenced by the large amount of pitch which it had worked out of the gallery. However, this individual tree seemed to be quite resistant by virtue of its copious oleoresin production.

Plate VII

Jeffrey Pine Beetle vs. Ponderosa Pine



A



B



C



D

A. Scattered distribution of infrequent attacks.

B. C. Closeups of excavated galleries - Thumb tacks (in C) denote beetle entrance holes. Broken ink lines denote extended path of gallery through bark; solid ink lines denote shorter phloem galleries. Arrows point to beetles trapped at upper end of galleries.

D. Closeup of typical small pitch tube.

Description of Test

No. of Cages: 3 (Py 14, 15, 16)

Beetles

Host: Jeffrey pine.

Location: Northern, eastside, Sierra - near Hat Creek, California

Rearing: Beetles were removed from the brood tree after the bark had been peeled off, and later the beetles were placed in the cages.

Attacks

Bark surface area: 30.9 sq. ft./tree

Number of attacks: 42-58.

Distribution of attacks: Attacks were scattered over the bole and not concentrated at the bottom as they were on the other tests involving this beetle.

Pitch tubes: Pitch tubes were about like those on the Jeffrey-ponderosa hybrid, somewhat smaller than those on the natural Jeffrey pine. Dead beetles were found only occasionally in the pitch tubes.

Galleries: The galleries formed by this beetle in this host were somewhat anomolous. When the beetle first entered the bark it moved laterally through the bark just outside of the phloem for a distance of 1/2 to 2". Then the gallery entered the phloem, and from this point of entrance into the phloem the gallery usually did not extend more than the length of a beetle. Generally the bark and phloem galleries were extended in an upward direction.

Significance: Although it is difficult to draw positive conclusions from these results, it appears from the lack of dead beetles in the galleries that the beetle can tolerate the oleoresin. On the other hand, the immediate cessation of gallery development once the beetle had entered the resin-producing, phloem area indicated that the beetle could not tolerate the resins. The small number of attacks from the relatively large beetle populations forced on these trees seemed to indicate that the beetles did not care for this host. Perhaps there were attacks analogous to those shown in Plate V which were not detected.

Plate VIII

Mountain Pine Beetle vs. Ponderosa Pine



A



B



C

- A. Distribution of attacks - Heaviest concentration in upper regions of the caged portion of the bole.
- B. Closeup of large bright yellow pitch tubes.
- C. Closeup of excavated galleries - Thumb tacks denote position of the pitch tubes. Phloem staining outlines upward extension of galleries.

Description of Test

No. of Cages: 3 (Py 6, 7, 8)

Beetles

Host: Sugar pine.

Location: Central Sierra, 6000 ft. - near Crystal Bay, Lake Tahoe, Nev.

Rearing: Natural emergence from infested brood logs placed inside of cage.

Attacks

Bark surface area: 37.5 sq. ft. (Py 6); 44.0 sq. ft. (Py 7); 26.9 sq. ft. (Py 8).

Number of attacks: 274 (Py 6); 314 (Py 7); 113 (Py 8).

Distribution of attacks: Attacks were concentrated on the upper bole. 7 - 12 attacks per square foot in the region of concentration. Many attacks (20 or more) above the caged portion of the bole.

Pitch tubes: Pitch tubes were rather large, yellowish-red in color and of a solid nature. Not runny as were the attacks of this beetle on sugar pine.

Galleries: Although the pitch tubes were large, the galleries only extended 1/2 - 1 " from the point at which they hit the phloem. These galleries were open, however, as if the beetles were actively working them. The galleries extended in an upward direction.

Significance: Apparently these beetles could tolerate the oleoresin of this tree as was expected. However, the flow of resin seemed to have been so copious that the beetles could not work it any longer, and they died from exhaustion.

Plate IX

Mountain Pine Beetle vs. Jeffrey Pine



A



B

- A. Dead beetles (arrows) trapped by the flow of pitch from the wound made to collect oleoresin from the test tree.
- B. Closeup of pitch tube - Arrows point to the two dead adults in the runny mass of pitch which they removed from the gallery before they succumbed. The test tree in this case was found to be a natural Jeffrey and ponderosa hybrid.

Description of Test

No. of Cages: 6 (Py 2, 3, 4, 5, 9, 10)

Beetles

Host: Ponderosa pine (Py 4, 5, 10); Sugar pine (Py 2, 3, 9).

Location: Central Sierra, 6000 ft. - near Crystal Bay, Lake Tahoe, Nev.

Rearing: Natural emergence from infested brood logs placed inside of cage.

Attacks

Bark surface area: 24.7 sq. ft. (Py 2); 31.6 sq. ft. (Py 3); 28.5 sq. ft. (Py 4); 28.5 sq. ft. (Py 5); 33.6 sq. ft. (Py 9); 75.9 sq. ft. (Py 10.)

Number of attacks: 35 (Py 2); 91 (Py 3); 14 (Py 4); 62 (Py 5); 30 (Py 9); 70 (Py 10).

Distribution of attacks: Attacks seemed to occur infrequently at random over the bark surface, but there was some tendency toward concentration on the upper portions of the bole.

Pitch tubes: Pitch tubes really were just small, spread-out masses of running pitch. Dead beetles were found in every pitch mass.

Galleries: The galleries penetrated directly to the phloem where they stopped abruptly.

Significance: The oleoresin of this host appeared to be toxic to this beetle, and the insect could not tolerate it even long enough to construct a semblance of a pitch tube. However, the larger size of this beetle, as compared with the western pine beetle, may account for its ability to move the small amount of pitch which it did move. The problem introduced by natural hybridization of the hosts also enters into this particular test (see page 4).

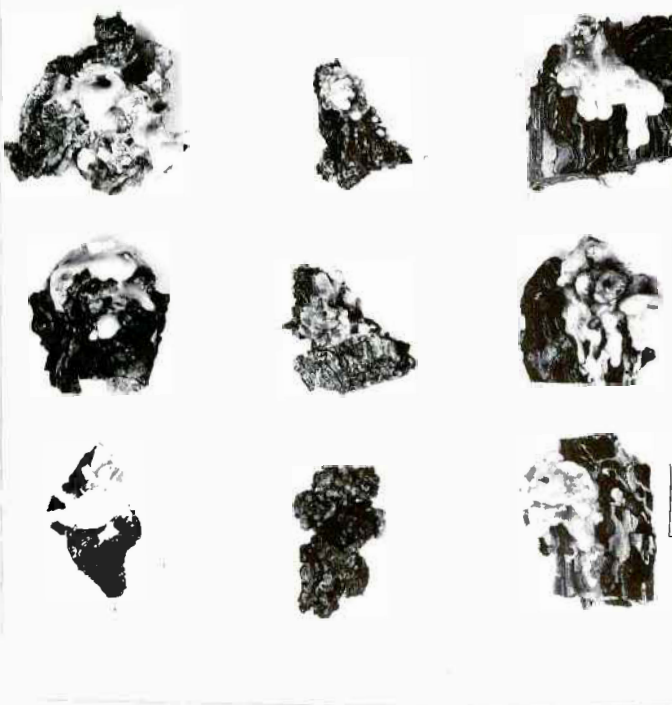
Plate XIV

DENDROCTONUS MONTICOLAE

Pitch Tubes on
Pinus jeffreyi

Pitch Tubes on
P. jeffreyi ponderosa

Pitch Tubes on
P. ponderosa



Comparative size of pitch tubes formed by mountain pine beetles on three different hosts. Preferred host is on the right.

Plate X

Mountain Pine Beetle vs. Sugar Pine



A



B

- A. Closeup of excavated galleries - Thumb tacks denote beetle entrance holes. Ink lines show direction and extent of galleries.
- B. Photo taken two months after photo A showing the extent of a gallery immediately adjacent to those shown in photo A.

Description of Test

Number of Cages: 3 (Py 11, 12, 13) Age of Trees:

Beetles

Host: Ponderosa pine.

Location: Central Sierra, 6000 ft. - near Crystal Bay, Lake Tahoe, Nev.

Rearing: Natural emergence from infested brood logs placed inside of cage.

Attacks

Bark surface area: 44.0 sq. ft. (Py 11); 57.5 sq. ft. (Py 12); 40.5 sq. ft. (Py 13).

Number of attacks: 170 (Py 11); 240 (Py 12); 209 (Py 13).

Distribution of attacks: Most of the attacks were concentrated on the upper portion of the bole. Occasionally there was an attack above the cage.

Pitch tubes: Pitch tubes were bright red and sticky or runny - not like the hard pitch tubes which this beetle formed on ponderosa pine. Many, dead, pitchy beetles were found on the bark.

Galleries: Most of the galleries, which were excavated, extended 6" in an upward direction from the point of entrance in a wavering, sometimes forked, manner. Eggs were found in some galleries. In most cases there were two dead adults in each gallery at different positions along the length of the gallery. Galleries were packed with a great deal of pitchy, red frass unless there were live beetles in the galleries, in which case the galleries were less pitchy and more open. The galleries just scored the sapwood, which in some cases was lightly blue-stained directly beneath the gallery.

Significance: Apparently this insect tolerated the oleoresin of this tree as was expected, and in addition, the flow of pitch did not seem to have been too excessive for the insects in one of the three test trees.

Plate XI



This photograph shows the type of apparatus used in collecting the oleoresin from each tree. One-fifth natural size.

Plate XII

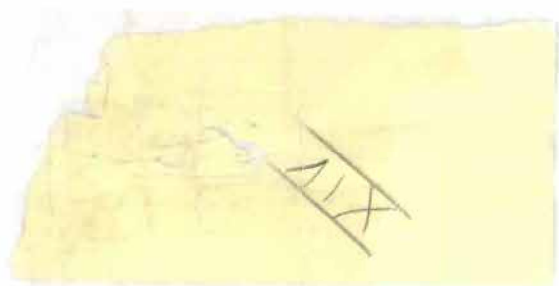


A



B

- A. A four-panel, plastic screen cage installed on a small ponderosa pine. The log wired to the test tree contains the broods of the insect being used in the test (mountain pine beetle). Pitch tubes are visible on the upper portion of the caged bole.
- B. A three-panel, bronze, screen cage installed on a small ponderosa pine. Other caged trees can be seen in the background.



RESINUCTOSUS MORTICOLAE

Pitch Tubes on
Pinus jeffreyi



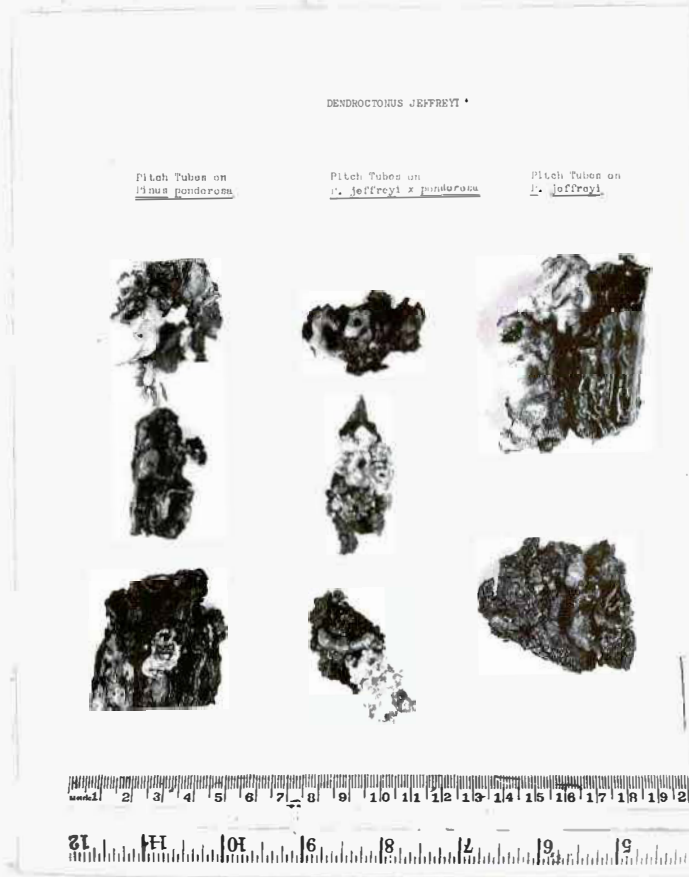
Pitch Tubes on
P. jeffreyi ponderosa



Pitch Tubes on
P. ponderosa



Plate XIII



Comparative size of pitch tubes formed by Jeffrey pine beetles on three different hosts. Preferred host is on the right.